NOTES ON THE GEOLOGY OF EASTERN GUATEMALA AND NORTHWESTERN SPANISH HONDURAS[1]

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CONTENTS

ILLUSTRATIONS

INTRODUCTION

The geology of Central America between the Isthmus of Tehuantepec and the line of the proposed Nicaragua Canal has been known only from the researches of Dr. Karl Sapper. These observations through a number of years have covered a vast amount of territory in a general way.[2] A brief examination of the Atlantic

[1] Published by permission of the Director, United States Geological Survey.

[2] K. Sapper, "Über Gebirgsbau und Boden des nördlichen Mittelamerika" (with geological map of Guatemala), *Peterm. Mitt.*, Ergänzungsheft 27, Heft 127, 1899; "Gebirgsbau und Boden des südlichen Mittelamerika" (with geological map of

Coast region between Trujillo, Spanish Honduras, and Livingston, Guatemala (Fig. 1), forms the subject of the few notes on the geology which are here presented. The petrography of the igneous rocks collected in Honduras is described in an accompanying paper by Professor Wilbur G. Foye, of Middletown, Connecticut.

Geologic investigations in the portion of Central America examined are conducted with difficulty owing to the primitive means of transportation inland beyond the coastal banana-plantation railroads and to the dense growth of tropical vegetation. Satisfactory exposures are confined to stream valleys. Also a scarcity of fossils in pre-Tertiary strata makes correlation and age determination exceedingly difficult. In Honduras fossils of Triassic and Cretaceous ages have been described; in Guatemala strata of Carboniferous (probably Pennsylvanian or upper Mississippian), Cretaceous, Eocene (?), Oligocene, Pliocene, and Pleistocene ages are known.[1] A lack of fossils and of detailed knowledge of the metamorphic rocks has made it impossible to determine whether they are in large part merely a metamorphosed portion of the Carboniferous or of an earlier Paleozoic system, as is suggested by the writer, or whether they are of pre-Cambrian age, as supposed by Sapper.

GENERAL GEOLOGY

Eastern Guatemala and northern Honduras lie on the south and southeast sides of the V-shaped Gulf of Honduras in latitudes 15° to 17° N. Commencing at the north the larger portion of the peninsula of Yucatan (Fig. 1), with the exception of the Cockscomb Mountains (an outlier of Paleozoic rocks in British Honduras), is composed of horizontal sediments of late Tertiary age which

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Honduras and Central America), *ibid.*, Ergänzungsheft 32, Heft 151, 1906; "Grundzüge der physikalischen Geographie von Guatemala," *ibid.*, Ergänzungsheft 24, Heft 113, 1894–95; "Die Alta Verapaz" (Guatemala) (with geological map of part of Guatemala), *Mitt. Geogr. Gesell. Hamburg*, XVII (1901), 78–224; "La geografía física y la geología de la península de Yucatán" (Chiapas and Tabasco states only), *Bol. Inst. geol. México*, No. 3, 1896; A. Dollfus et E. de Mont-Serrat, *Mission scientifique au Mexique et dans l'Amerique Central, Géologie*, Paris, 1868; E. Suess (de Margerie), *La Face de la terre*, III (3) (1913), 1264–74.

[1] Bailey Willis, *Index to the Stratigraphy of North America*, U.S. Geol. Surv., Professional Paper No. 71, 1912.

form a region of little relief. A belt of gently folded Cretaceous and Oligocene strata, principally limestones with an east-west trend, separates the lowlands on the north from the high mountain ranges in the south. The relief of the mountains carved in rocks

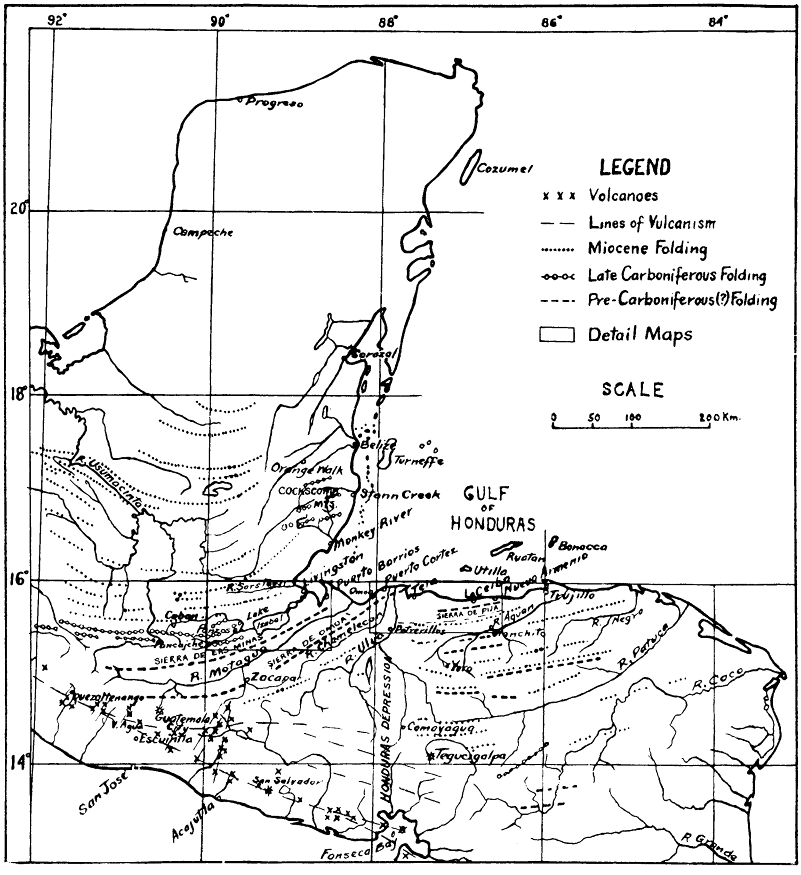

FIG. 1.—Tectonic lines in Honduras and Guatemala, modified from Sapper (Eighth International Geographical Congress, 1904 [Washington, 1905], Fig. 1).

of these ages is of the order of 1,000 to 2,000 feet. Mountains of metamorphic and intrusive rocks forming conspicuous parallel ranges extend from southwestern Mexico and central Guatemala through northern Honduras and meet the coast at an angle on the south side of the Gulf of Honduras. The relief of the mountains

is 1,000 to 4,000 feet and the height of some more than 5,000 feet.[1]

Plateaus and irregular ridges of low relief, but with elevations of 3,000 to 4,000 feet, are found west and southwest of the mountains composed of metamorphic rock. This region is composed of early Tertiary or possibly late Mesozoic volcanics.[2] In places folded sedimentary rocks appear with the volcanics. Farther inland and nearer the Pacific Coast the ridges of folded volcanics give way to broad plateaus that are 3,000 to 4,000 feet above sea-level and are separated more or less completely from one another by rims of low hills. The plateaus slope gently toward the east. Young, deep gulches are rapidly dissecting the plateau surfaces. Exposures thus made show that the surfaces were formed in an earlier cycle of erosion by overloaded streams under conditions of aridity and that deep incision is now taking place for the first time. The summit of the plateau forms the continental divide—a volcanic plateau on which stands Guatemala City at an elevation of 4,900 feet.

On the Pacific slope in Guatemala the high plateaus are bounded by a row of active and recently extinct volcanoes which rise in many cases directly to elevations of 10,000 to 13,513 feet from the low plain that forms the coast. The alignment of the volcanoes is parallel to the coast and diverges sharply from the trend of the older mountain ranges. The plain at the coast is composed of volcanic ejectamenta and shows no signs of uplift; hence it would not be called a coastal plain according to some definitions of that term. It is so level that 20 miles inland, at Santa Maria, the elevation is only 416 feet. From here the surface gradually rises to an elevation of 1,100 feet at Escuintla, 27 miles inland. Only 40 miles inland the dormant volcano Agua, near Escuintla, is 12,140 feet high.

[1] Elevations of 8,000 feet for Congrejal and Bonita peaks, near La Ceiba, Honduras, as given on a chart of the U.S. Coast and Geodetic Survey, evidently should be 4,000 feet.

[2] Vulcanism is thought to have begun during the Eocene in Mexico (J. G. Aguilera, *Compte Rendu* [10th Int. Geol. Cong., Mexico, 1906], p. 1157) and to have been in progress during the Oligocene in Nicaragua (C. W. Hayes, quoted by Sapper, *Zeit. Ges. f. Erdkunde* [Berlin, 1902], p. 513).

Rainfall and humidity have everywhere an important bearing on vegetation and therefore on surface features. The high plateaus behind mountains which catch all the moisture suffer from aridity and afford scant vegetation. At lower elevations, but again in the lee of the mountains, there are deserts, as at Zacapa, supporting only cactus. Near the sea both coasts receive an overabundance of rainfall with accompanying great humidity. On both sides of the Isthmus the northeast trades are the prevailing winds, but on the Pacific Coast the winds are variable except during winter of the northern latitudes.

Statistics for an average year show rainfall on the Pacific Coast (elevation 600 feet) of 240 inches; at Guatemala City (elevation 4,900 feet) of 60 inches; at Quirigua (elevation 240 feet), 57 miles from Puerto Barrios, but behind a mountain range, of 99 inches; at Panzos (elevation 50 feet), 100 miles inland, of 115 inches; at Puerto Barrios, on the Atlantic, of about 200 inches. The rainy season on the Pacific Coast is May 15 to October 15, on the Atlantic Coast June 15 to August 15 and September 15 to February 15. The best weather in Guatemala and Honduras as a whole is therefore in the winter and spring of the northern latitudes, and only during this dry season can geologic work be carried on satisfactorily in the coastal regions.

GEOLOGY

Spanish Honduras.—Northern Honduras consists of two mountain ranges of the metamorphic series, each with many subsidiary branches. The first of the parallel ranges forms a portion of the boundary line between Guatemala and Honduras (Figs. 1 and 4) and is variously known as the Sierra de la Grita, Sierra de Merendon, Sierra del Espiritu Santo, and the Sierra de Omoa—the Omoa Mountains. This range lies for a distance between the Motagua and Chamelecon rivers (Fig. 2), but east of the broad Chamelecon-Ulua lowlands it reappears in Punta Sal and in the Bay Islands (Utilla, Ruatan, and Bonacca). The second range, Sierra de Pija (Fig. 1), lies west of the Ulua River between the various short streams on the Atlantic shore and the Aguan River (Yoro-Olanchito) valley. This range extends into the sea east of Trujillo.

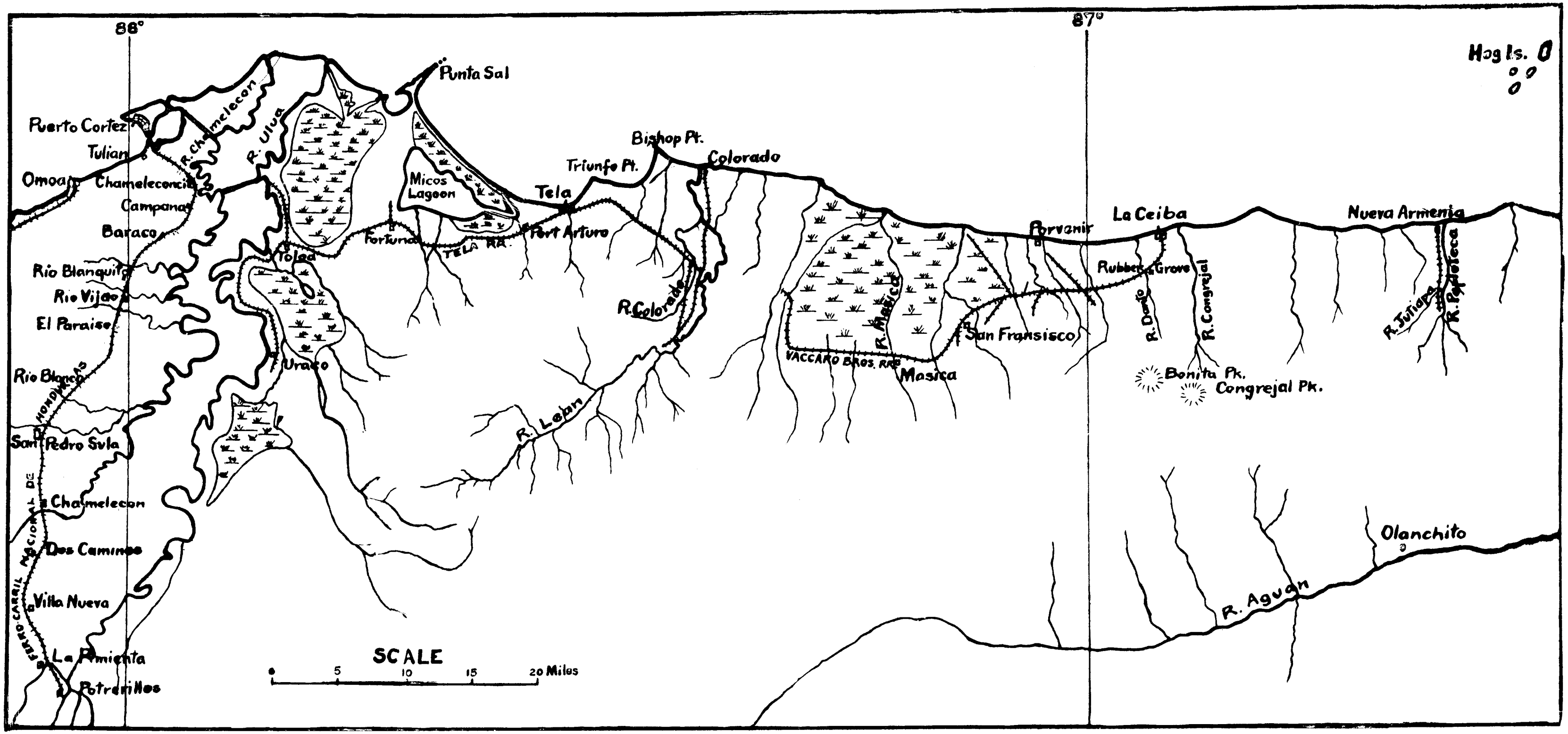

FIG. 2.—Map of the northwestern portion of Honduras

Considered as a whole, the Omoa Range consists principally of slates, schists, quartzites, and limestones, while the Sierra de Pija is composed of mica schists and quartzites intruded by granodiorites, diorites, and tonalites.[1] The igneous rocks as a whole may represent phases of a single large batholith. The intrusions have a lineal arrangement in a N. 50°–80° E. direction and occupy the region between the sea and the summit of the range. Basalt of Tertiary or Quaternary age occurs in the Sierra de Omoa at Chameleconcito, near Puerto Cortez, and on the island Utilla. Sandstones and conglomerates of late Tertiary age are found along the shore cliffs between Puerto Cortez and Omoa.

The age of part of the metamorphic rocks is known to be Paleozoic; the age of the remainder is thought to be Paleozoic. Carboniferous fossils were found by the writer in metamorphosed, horizontally bedded limestones in the hills west of Puerto Barrios, Guatemala, not far from the line of strike of the marbles in the Sierra de las Minas, north of the Motagua River valley, and of other metamorphic rocks. If the metamorphic rocks are of Paleozoic age the batholithic intrusions must have appeared during the subsequent folding, presumably at the close of the Paleozoic.

Along the continuation of the Sierra de Omoa at Punta Sal, north of Tela (Fig. 2), black slates striking N. 70° E. and dipping 55° N. form a prominent ridge. The main range of the Sierra de Omoa consists of mica schists, quartz schists, and quartzites, as seen in the exposures along the Ferrocarril Nacional de Honduras between Chameleconcito and Baracoa. Limestone appears at Baracoa, where springs of cool carbonate water have built large calcareous tufa terraces. At Rio Vijao marble has been quarried for ballast. The marble may be seen as far as Rio Chaloma (El Paraiso), but is replaced by tonalite or granodiorite from this point to San Pedro Sula. No observations were made on the Sierra de Omoa near the Guatemala boundary, but at Quebradas de Oro, in Guatemala, placer gold is mined hydraulically, the country rock being hornblende schist penetrated by quartz veins.

[1] Described in "Notes on Collection of Rocks from Honduras, Central America," by Wilbur G. Foye, in this issue of the *Journal of Geology*.

Gently folded Tertiary or possible early Pleistocene sand, gravel, and clays are exposed in sea cliffs 40 feet in height between Tulian, south of Puerto Cortez, and Omoa. Bedding in these sediments is on the whole regular, but within individual strata there is cross-bedding. The gravel is composed in part of bowlders 3 inches to a foot in length, packed together as if deposited in streams and not in the sea. No shells or fragments of wood were found, although in somewhat similar beds at Livingston, Guatemala, casts of marine shells of Pleistocene (?) age were found.

Olivine basalt composes a number of small, rounded hills one mile south of Chameleconcito and near the National Railroad. The hills are of the typical form developed on weathered *aa* flows. A recent, perhaps Pleistocene, age must be assigned to the basalt flows here and on Utilla Island.[1] Hot springs, apparently connected with the same vulcanism, are very common along the coastal region from the Gulfete (Rio Dulce), Guatemala, to Trujillo, Honduras, especially near the foot of the mountains between Tela and Trujillo.

Between the Sierra de Omoa and the Sierra de Pija in the vicinity of the National Railroad tonalites appear in low hills north and west of San Pedro Sula. This city is built on a broad gravel fan extending from the mountains on the south. In these mountains the contact effect of diorites with metamorphosed schists may be seen. A tonalite similar to that exposed near San Pedro Sula outcrops in the Ulua River and in the hills near Uraca, a native village at the present southeastern terminus of the Tela Railroad, 36 miles by rail from Tela. From Uraca eastward diorites, tonalites, and other igneous rocks invade schists and quartzites, as described by Professor Foye.

[1] The distribution of the basalt is in accord with the researches of A. Bergeat ("Zur Kenntnis der jungen Eruptivgesteine der Republik Guatemala," *Zeit. d. d. Geol. Gesell.*, XLVI [1894], 131–57), who shows a conspicuous arrangement of volcanics according to types in the few specimens of Guatemalan volcanics examined. Basic and acidic types, basalt and rhyolite, are practically confined to the region east of the Pleistocene volcanoes, while the intermediate type, andesite, is the conspicuous component of the surficial rocks of the Pacific volcanoes. A predominance of volcanics of an intermediate type on the immediate borders of the Pacific Ocean is also suggested by B. Koto to hold true in Japan (*Jour. Geol. Soc. Tokyo*, XXII [1915], 124; XXIII [1916], 127).

South of San Pedro Sula, at Chamelecon, intensely folded mica schist is exposed. The foliation strikes N. 80° E. South of Chamelecon and of the Chamelecon River, crystalline limestones, in which no trace of bedding or of fossils were found, extend from Dos Caminos to Potrerillos, the terminus of the National Railroad. One mile south of La Pimienta the limestone is overlain by volcanic ash and by lava flows. Sapper maps the limestone as Upper Cretaceous.[1]

In the Sierra de Pija between the Ulua River and Trujillo igneous and metamorphic rocks were found in every stream examined. Tonalites and porphyries are the most common igneous rocks, with paleovolcanics on the west, especially in the vicinity of La Ceiba and in the Congrejal Valley south of La Ceiba. The metamorphic rocks of sedimentary origin are schists and slates with cleavage striking N. 60° E. parallel to the range.

The Bay Islands, lying 20 to 35 miles off the north shore of Honduras, consist of three large islands, Utilla, Ruatan, and Bonacca (Fig. 1), with several small islands and cays. While the axes of the large islands are not quite parallel, they are all part of the Sierra de Omoa. Historically the islands are known from the fact that Columbus landed on Bonacca on his fourth voyage in 1602, and from the fact that they are inhabited by English-speaking people and were not ceded to Honduras by Great Britain until 1860.

Bonacca Island is 10 miles long and $2\frac{1}{2}$ miles in maximum width, and the highest elevation is 1,200 feet. According to Sapper the island is composed of mica schist with serpentine (marble?) on the western end. Ruatan is 33 miles long, 3 miles wide, and the highest elevation is 800 feet. Sapper found mica schist with some crystalline limestone and amphibolite on the island.[2] Utilla is $7\frac{1}{2}$ miles long and $2\frac{1}{2}$ miles wide. The western two-thirds of the island is composed of coral reefs, lagoons, and swamps, but the eastern third consists of a rolling upland averaging 40 feet in height, surmounted by Pumpkin Hill, 290 feet high, and Stuert Hill, 169 feet high. The rolling surface is underlain by olivine basalt flows.

[1] *Peterm. Mitt.*, Ergänzungsheft 32, Heft 151 (1905), geologic maps.

[2] *Ibid.* (1905), pp. 17–18.

Stuert Hill consists of olivine basalt and agglomerate, Pumpkin Hill of palagonite tuff of basaltic composition containing fragments of coral reef limestone. The tuff with its inclusions is indistinguishable from that which composes the well-known cones on the island Oahu, Hawaiian Islands, near Honolulu. Stuert Hill was evidently

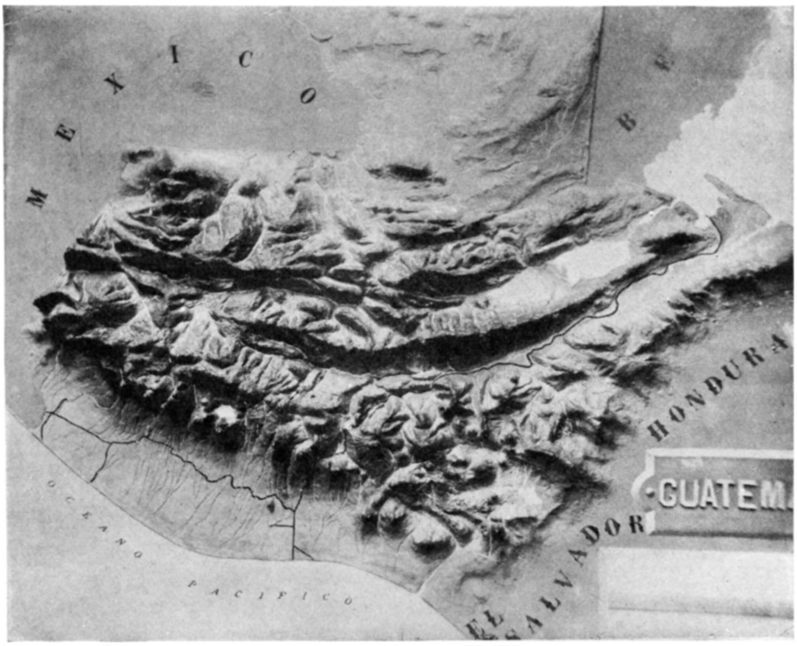

FIG. 3.—Relief map of Guatemala, showing the long Polochie–Lake Izabal Valley on the north, Motagua Valley in the center, the row of volcanoes facing the Pacific, and the broad plain at the Pacific Coast. The International Railroad runs from Puerto Barrios, on the Atlantic, up the Motagua Valley, past Guatemala City in the high plateaus to San Jose, on the Pacific. A branch line runs from Santa Maria northwestward to the Mexican boundary.

a center of volcanic activity in Quaternary time—perhaps the principal one for the island—while Pumpkin Hill probably resulted from a local submarine eruption breaking through coral reefs. Small coral reefs are found on the summit of Stuert Hill, and a small elevation called Brandon Hill is composed entirely of limestone. The age of these reefs is unknown, but is probably quite

recent. The only evidence of pre-Tertiary rocks on the island found by the writer was a block of mica schist in the cemetery. The Hog Islands, near Nueva Armenia, at the mouth of the Paploteca River, are composed, according to Sapper, of mica and graphite schist.[1]

Guatemala.—A relief map of eastern Guatemala (Fig. 3) shows two remarkable east-west valleys, the Motagua and the Polochie–Lake Izabal, separated by the Sierra de las Minas range, which follows a curve slightly concave to the north. The region south

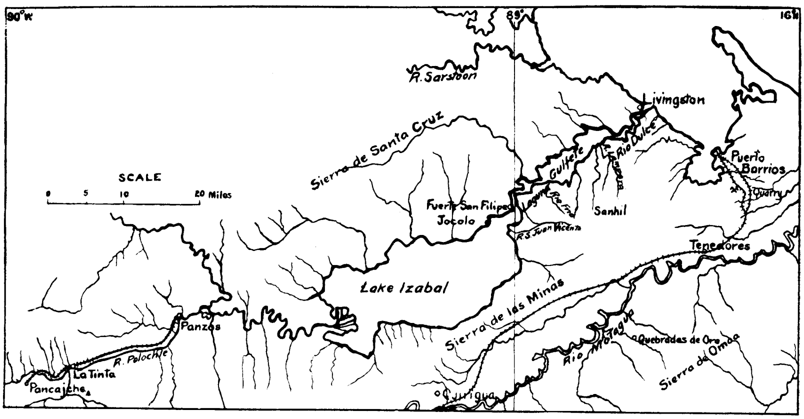

FIG. 4.—Map of the eastern portion of Guatemala

of the Motagua Valley is formed by the continuation of the Sierra de Omoa. The Sierra de las Minas is composed of sedimentary and metamorphic rocks of Carboniferous and of pre-Carboniferous age. North of Lake Izabal the rugged country of gradually diminishing relief is underlain by folded limestones of Cretaceous age.

Fossils of Carboniferous age were collected by the writer in two localities: in the mountains west of Puerto Barrios along the pipe line to the reservoir which supplies that town, and on the line of the Panzos Railroad, along the south bank of the Polochie River near Pancajche, the western terminus of the line (Fig. 4). At the former locality poorly preserved fossils were found in weathered surfaces of a massive, bluish limestone which is metamorphosed and cut by innumerable calcite veins averaging one-quarter of an

[1] *Peterm. Mitt.*, Ergänzungsheft 32, Heft 151 (1905), pp. 17–18.

inch in width. The age of the fossils was determined by Dr. E. O. Ulrich as probably Upper Mississippian or Lower Pennsylvanian. Excellent exposures of the same rock were seen in a quarry 7 miles inland from Puerto Barrios along the old line of the International Railways of Central America. The Pancajche fossils, a large species of *Fusulina*, of Pennsylvanian age according to the determination of Professor P. E. Raymond, were found in dense, bluish limestone interbedded with slate and with mica schist dipping 40°–80° S. to S.E. These rocks belong to the Santa Rosa formation of Sapper.[1]

The Sierra de las Minas range is mapped by Sapper[2] as being composed, from south to north, of serpentine, crystalline schist and gneiss, granite (in part of range), Santa Rosa formation schist of Carboniferous age (as at Pancajche), and Carboniferous limestone. The belt mapped as serpentine coincides with a belt of very good quality white, crystalline marble which composes the south flank of the mountains and is now being quarried on an extensive scale 15 miles northwest of Zacapa (Fig. 1). The marble is said to be equal in quality to any in the United States.

An unconformity is supposed to exist on the north side of the mountains between the crystalline rocks and the fossiliferous Santa Rosa formation schists. The evidence of this unconformity is stated by Sapper to be the presence of occasional pebbles of crystalline schist as large as nuts in the Santa Rosa schists.[3] On the strength of this evidence Sapper places the crystalline schists in the pre-Cambrian, although he admits that the rocks cannot always be distinguished. Confirmatory evidence of the existence of this unconformity is needed, for the degree of metamorphism of the rocks increases from north to south in both Guatemala and Honduras. Mountain-building movements at the close of the Paleozoic will account for all the variations in the degree of metamorphism of the Paleozoic rocks. Intensely metamorphosed and recrystal-

[1] *Mitt. Geogr. Gesell. Hamburg*, XVII (1901), with lists of fossils collected by him.

[2] *Peterm. Mitt.*, Ergänzungsheft 27, Heft 127, 1899; *Mitt. Geogr. Ges. Hamburg*, XVII (1901).

[3] *Mitt. Geogr. Gesell. Hamburg*, XVII (1901); Dollfus et Mont-Serrat (*op. cit.*) also report an unconformity.

lized rocks such as would be expected in a pre-Cambrian terrane are absent.

A block of almost horizontally bedded uppermost Oligocene limestone forms a flat-topped ridge 3 miles wide at Livingston. This block was probably faulted down against the Carboniferous limestones of the Puerto Barrios reservoir during the late Miocene folding of the region, but its present width may have been determined by later movements. Through this block the Rio Dulce cut a narrow gorge during the latest uplift of the region; the gorge is 300 to 500 feet in width and 175 to 300 feet in depth. The fauna collected in the walls of the gorge consists principally of corals and oysters, but it is not a coral-reef formation.[1]

Oligocene limestone, which may be called the Rio Dulce limestone, is undoubtedly more widespread in northern Guatemala than has hitherto been supposed. Limestones forming low hills on the north shore of Lake Izabal at Jocolo (Fig. 4) with a N. 50°–80° E. strike and apparently vertical dip resemble the Rio Dulce limestone lithologically and in obscure fossil content. Likewise blocks of limestone collected at Fuerte San Filipe, at the entrance to Lake Izabal, show spines and other fragments of echinoids on weathered surfaces and are probably part of the same formation. As Sapper mapped the Livingston–Sierra de Sta. Cruz region as Upper Cretaceous,[2] part of his extensive Cretaceous area may be of Tertiary age.

Slightly consolidated quartz gravels and clays containing casts of marine shells of Pliocene or Pleistocene age are found in the lowest of the terraces on which Livingston is built. These gravels are probably a part of the formation which is exposed along the Omoa and Tulian shore of Honduras, as already described. No evidence of folding was seen, however, in the Livingston exposures. Fossiliferous white clays containing chert pebbles and interbedded black lignite seams of Pleistocene or possible Pliocene age underlie the region between Sanhil (Sierra de las Minas), the Rio Dulce

[1] Dr. T. W. Vaughan, of the U.S. Geological Survey, identified the fragmentary fossils as resembling those of the Emperador limestone of the Canal Zone (the Empire limestone of R. T. Hill).

[2] *Peterm. Mitt.*, Ergänzungsheft 27, Heft 127 (1899), geologic map.

limestone ridge at Livingston, and Lake Izabal (Fig. 4). The fossils collected were identified by Dr. Paul Bartsch as the fresh-water gastropod *Sphaeromelania lacustris* Morelet (?).[1] Lignite beds 2 to 3 feet thick occur in several streams emptying from the south into the Gulfete and Laguna between Rio Dulce and Lake Izabal—Rio Lampara, Rio Frio, Rio Juan Vicente—and lignite beds are reported near Livingston east of the Rio Dulce limestone. The white clays and lignite beds may have a thickness of a few hundred feet. They are folded, dips as high as 8 degrees being observed. Rounded chert bowlders, apparently similar to those associated with these clays, are reported by Sapper to be associated with chalk and limestone in northern Yucatan and in British Honduras between Belize and Orange Walk.

British Honduras.—Southern British Honduras is underlain by a continuation of the Oligocene Rio Dulce limestone and of the Cretaceous limestone of Guatemala. Prominent ridges of limestone, probably the Rio Dulce limestone, form the hills along the Sarstoon River near the southwest corner of British Honduras and at Punta Gorda, British Honduras, on the coast. North of Punta Gorda the flat shore is bounded by the most extensive barrier reef in the Atlantic Ocean. Behind the cays and reefs is the closed inland passage up the Yucatan Coast with narrow channels through the reefs. Farther north the large island Cozumel, composed of limestone reefs elevated 10 to 30 feet above sea-level, lies off the flat, monotonous coast of Yucatan.

Geological observations on British Honduras have been made by Sapper and by others.[2] The Cockscomb Mountains of British Honduras are described as a horst about 45 miles in diameter with mountains as high as 3,050 feet. Sapper speaks of granites and quartz porphyries, argillaceous schists, quartzites, and crinoidal Carboniferous limestone striking in a northeast to east direction. North of these mountains and extending over the large department Peten, Guatemala, late Tertiary limestones are so soluble that the

[1] Collected near Rio Frio. From shells eaten by the Indians Dr. Bartsch identified *Euglandina carminensis* Morelet, *Sphaeromelania corvina* Morelet, *S. glaphyra immenis* Morelet, and *S. glaphyra* Morelet.

[2] *Peterm. Mitt.*, Ergänzungsheft 27, Heft 127, 1899; E. Suess (de Margerie), *La Face de la terre*, III (3) (Paris, 1913), pp. 1264–74.

drainage is largely underground. One cave on the Belize River is said to rival the Mammoth Cave in size.

RECENT CHANGES OF LEVEL

A stillstand of the Central American coast is scarcely possible, as is indicated by the frequent earthquakes which disturb the country. In Guatemala perceptible earthquakes are frequently of daily occurrence on the high plateau, as at Guatemala City, but are relatively rare on the Atlantic shore. Changes of level are recorded along the Atlantic shore in elevated coral reefs and terraces and in drowned valleys.

Evidence of uplifts are seen on Utilla Island. A coral reef covers the summit of Stuert Hill, 169 feet high, and less conspicuous reefs are found at lower levels, the lowest being a recently elevated reef 3 feet high on the eastern side of the island. The same recent uplift may account for the narrow bench in front of a wave-cut cliff of basalt on which the town Utilla has been built. Extensive coral reefs and cays surround Utilla Island, but they nowhere skirt the mainland of Honduras or Guatemala in the regions examined.

Lagoons fronted by a continuous sandy beach skirt the northern coast of Honduras. The beaches are tied to rocky headlands and to river deltas, but they extend across the mouths of rivers in the form of bars 2 to 6 feet in depth. A normal tide of only about one foot and littoral currents from west to east have favored the construction of the bars. No vertical movements are connected with their formation.

Elevated benches obscured by dense vegetation probably occur all along the coast, but these benches are evidently not very recent, as they lack well-defined facets toward the coast except at Livingston and near Puerto Cortez. At Livingston, Guatemala, the town is built on terraces 35 and 55 feet in height. Across the bay from Puerto Cortez, at Tulian, distinct 40- and 60-foot terraces were seen. No corals or marine shells were found on any of these terraces. Shells are common on the present beach, but coral fragments are absent.

Evidence of earlier subsidence in both Honduras and Guatemala was seen in the broad river valleys filled with alluvium in which the

streams are now cutting narrow channels, and in the terraces along the continental shelf. Coast charts show a shelf about 5 miles wide with terraces at depths of about 15 and 30 fathoms in the vicinity of Utilla Island. The antecedent stream, Rio Dulce, Guatemala, flows through a rock gorge, and the depth of the water through the gorge and directly behind the bar is 40 feet. No other stream along the coast has a rock bed at sea-level. Therefore data on subsidence are very fragmentary.

TECTONICS

Guatemala and Honduras are composed of two mountain systems (Fig. 1): the Pacific Cordillera, now little more than a belt of high plateaus covered with young volcanics, and the Caribbean Cordillera, consisting of east-west ranges. On the north the tectonic lines of Yucatan trend toward the Isle of Pines; in the center of Guatemala they trend toward a 3,000-fathom deep; on the south, in Honduras, they trend toward Jamaica. The two systems are in striking contrast; from the Atlantic, broad, structural valleys with a maximum length of 200 miles (Fig. 3) stretch almost across the Isthmus; from the Pacific, short, precipitous valleys extend to the high plateau between the volcanoes and almost disappear on the low plain near the coast.

It has been pointed out above that successively older formations appear on the Caribbean side of the Isthmus from north to south and that the Tertiary and younger volcanics are largely confined to the high plateau forming the backbone of the Isthmus. Pleistocene volcanoes are aligned on the inland edge of the Pacific plain parallel to the coast. The lack of any evidence on the Pacific side of Guatemala of valleys of such size that they would not be concealed by late Tertiary and more recent volcanics, the absence of a coastal plain showing uplift, and the remarkable alignment of the volcanoes point to a possible fracture zone on the western side of which a portion of the Pacific Cordillera has subsided. Along one of the principal lines of subsidence at the intersection of cross-fractures the volcanoes have been built.[1] Uniformly great depths in the

[1] The fracturing is similar to, but more complicated than, that in the Hawaiian Islands (S. Powers, "Tectonic Lines in the Hawaiian Islands," *Bull. Geol. Soc. Amer.*, XXVIII (1917), 501–14).

Pacific Ocean at no great distance from shore and the parallelism to the coast line of the submarine contours are not unfavorable to the theory of subsidence.

Diastrophic movements of considerable magnitude have taken place in Central America at three different periods: at or before the close of the pre-Cambrian, at the close of the Paleozoic, and during the late Miocene. A later movement may be dated as late Pliocene or Pleistocene. The Cordilleran axes were developed during the folding at the close of the Paleozoic, the folding being most intense toward the south. Miocene movements, though less intense, developed parallel Cordilleran trends of the Caribbean system and initiated the cycle of erosion in which the greater part of the dissection of the present mountains was accomplished. Vulcanism undoubtedly began in the present central portion of the Isthmus before the Miocene deformation, as the earlier volcanics are steeply folded. Pliocene and Pleistocene (?) sediments from Yucatan southward through Honduras show evidence of both vertical and tangential movements, tangential movements being especially notable in the youngest sediments of the Atlantic Coast region near Puerto Cortez and Omoa, Honduras, and Lake Izabal, Guatemala.